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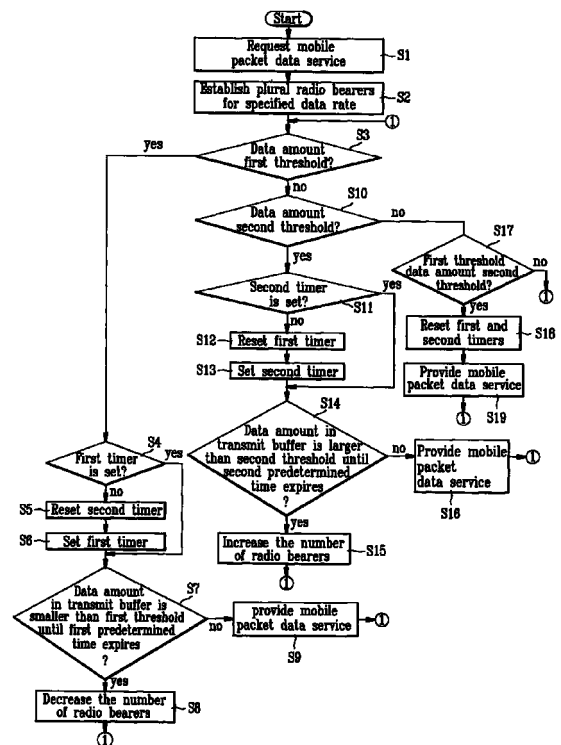
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(54) Controlling asymmetric dynamic radio bearers in mobile packet data communications system

(57) The method and apparatus for controlling asymmetric dynamic radio bearers in a mobile packet data communications system involves use of the radio bearers for the specified data rate corresponding to the data rate according to the radio packet data service to activate a predetermined number of radio bearers only according to the amount of transmit data and vary the data rate, thereby making it possible to efficiently use the radio resources and prevent excessive power consumption and signal interference. The method for controlling asymmetric dynamic radio bearers in a mobile packet data communications system includes the steps of: (a) establishing a plurality of radio bearers having a predetermined data rate; (b) examining the amount of data stored in a transmit buffer during transmission of mobile packet data; and (c) transmitting the mobile packet data with the number of the radio bearers increased or decreased according to the amount of data.

FIG.4



Description**BACKGROUND OF THE INVENTION**Field of the Invention

[0001] The present invention generally relates to a mobile packet data communications system and, more particularly, to a method and apparatus for controlling asymmetric dynamic radio bearers in a mobile packet data communications system.

Discussion of Related Art

[0002] There have been developed and provided various services concerning data such as text, audio and video data in the recent new radio communications system, for example, PCS and IMT-2000, etc. Further, the system provides the data service at a fixed data rate in a bi-directional way.

[0003] The data rate is controlled by an MAC (Medium Access Control) provided in the individual apparatus.

[0004] Hereinafter, reference will be made in connection with the accompanying drawings as to a description of a mobile packet data communications system in accordance with prior art.

[0005] FIG. 1 is an illustrative diagram of a related art mobile packet data communications system, which includes a mobile station 1 requesting a radio data service and a network 2 providing the radio data service to the mobile station 1.

[0006] The mobile station 1 includes an MAC 1a for controlling transmit data according to the data rate corresponding to the requested radio data service and transmitting them through a transmit buffer 1b.

[0007] The network 2 includes an MAC 2a for examining the data rate corresponding to the radio data service requested by the mobile station 1 and a transmit buffer 2b through which the radio data service is transmitted to the mobile station at the data rate.

[0008] Now, a detailed description will be made as to the operation of the related art mobile packet data communications system as constructed above.

[0009] First, when the MAC 1a of the mobile station 1 requests the network 2 to provide a specified data service, the MAC 2a of the network 2 examines a fixed data rate corresponding to the data service.

[0010] Upon examining the fixed data rate, the network 2 informs the mobile station 1 of the data rate to make a condition for the data service and providing the data service for the mobile station 1 with radio bearers for the data rate.

[0011] The radio bearers for the fixed data rate are controlled respectively by the MACs 1a and 2a to provide a symmetric data service communicated between the mobile station 1 and the network 2.

[0012] In such a related art mobile packet data communications system, the packet data are transmitted by

using all the radio bearers at a fixed data rate since the data rate corresponding to the data service communicated between the mobile station and the network is fixed, thereby causing problems such as inefficient utility of the radio resources, excessive power consumption and signal interference.

SUMMARY OF THE INVENTION

[0013] Accordingly, it is an object of the present invention to provide a method and apparatus for controlling asymmetric dynamic radio bearers in a mobile packet data communications system in which the data rate can be varied by activating only a part of the radio bearers for a predetermined data rate according to the amount of data to be transmitted in a specified mobile data service.

[0014] To achieve the first object of the present invention, there is provided a method for controlling asymmetric dynamic radio bearers in a mobile packet data communications system including the steps of: (a) establishing a plurality of radio bearers having a predetermined data rate; (b) examining the amount of data stored in a transmit buffer during transmission of mobile packet data; and (c) transmitting the mobile packet data with the number of the radio bearers increased or decreased according to the amount of data.

[0015] In the step (c), the amount of data stored in the transmit buffer is compared with first and second thresholds TH_{LOW} and TH_{HIGH} , and the number of the radio bearers is decreased by one when the amount of data is lower than the first threshold TH_{LOW} and increased by one when the amount of data is higher than the second threshold TH_{HIGH} . And, the number of the radio bearers is not changed when the amount of data stored in the transmit buffer is kept between the first and second thresholds TH_{LOW} and TH_{HIGH} .

[0016] In the step (c), the number of the radio bearers is decreased by one when the amount of data stored in the transmit buffer keeps lower than the first threshold TH_{LOW} until a predetermined time expires and increased by one when the amount of data stored in the transmit buffer keeps higher than the second threshold TH_{HIGH} until the predetermined time expires.

[0017] The first and second thresholds TH_{LOW} and TH_{HIGH} are between hysteresis values for preventing frequent changes of the amount of data stored in the transmit buffer. The hysteresis values comprise first and second hysteresis values are opposite to each other with the first threshold TH_{LOW} interposed therebetween and separated from the first threshold TH_{LOW} at a predetermined distance, and third and fourth hysteresis values are opposite to each other with the second threshold TH_{HIGH} interposed therebetween and separated from the second threshold TH_{HIGH} at a predetermined distance.

[0018] The above steps are supported in MAC (Medium Access Control) protocols of a mobile station

and a network.

[0019] There is further provided an apparatus for controlling asymmetric dynamic radio bearers in a mobile packet data communications system including: a transmit buffer for temporarily storing transmit data according to a radio data service; and controlling means for establishing a plurality of radio bearers for transmission of the transmit data at a data rate corresponding to the radio data service, examining the amount of data stored in the transmit buffer and increasing or decreasing the number of the radio bearers.

[0020] The controlling means determines first and second thresholds for increasing or decreasing the number of the radio bearers. The first and second thresholds TH_{LOW} and TH_{HIGH} are between hysteresis values for preventing frequent changes of the amount of data stored in the transmit buffer. The hysteresis values include first and second hysteresis values are opposite to each other with the first threshold TH_{LOW} interposed therebetween and separated from the first threshold TH_{LOW} at a predetermined distance, and third and fourth hysteresis values are opposite to each other with the second threshold TH_{HIGH} interposed therebetween and separated from the second threshold TH_{HIGH} at a predetermined distance.

BRIEF DESCRIPTION OF THE ATTACHED DRAWINGS

[0021] The accompanying drawings, which are included to provide a further understanding of the invention and are incorporated in and constitute a part of this specification, illustrate embodiments of the invention and together with the description serve to explain the principles of the drawings:

[0022] In the drawings:

FIG. 1 is a diagram illustrating the structure of a mobile packet data communications system according to related art;

FIG. 2 is a diagram illustrating transmission of a variable radio bearer in a method for controlling asymmetric dynamic radio bearers in a mobile packet data communications system according to the present invention;

FIG. 3 is a diagram illustrating the condition of a transmit buffer controlled by the method for controlling asymmetric dynamic radio bearers in a mobile packet data communications system according to the present invention; and

FIG. 4 is a flow chart illustrating a procedure for controlling asymmetric dynamic radio bearers in a mobile packet data communications system according to the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENT

[0023] Hereinafter, reference will be made in connection with the accompanying drawings as to a detailed description of a method for controlling asymmetric dynamic radio bearers in a mobile packet data communications system in accordance with a preferred embodiment of the present invention.

[0024] An apparatus for controlling asymmetric dynamic radio bearers in a mobile packet data communications system according to the present invention includes the same components as illustrated in FIG. 1, i.e., a mobile station 1 requesting a radio data service and a network 2 providing the radio data service to the mobile station 1. These components have their functions newly defined in the present invention.

[0025] The mobile station 1 includes a transmit buffer 1b for temporarily storing transmit data according to the requested radio data service, and an MAC 1a for establishing a plurality of radio bearers used to send the transmit data at a data rate corresponding to the radio data service and examining the transmit buffer 1b to increase or decrease the number of the plural radio bearers established.

[0026] The network 2 includes a transfer buffer 2b for temporarily storing the transmit data according to the radio data service requested by the mobile station 1, and an MAC 2a for establishing a plurality of radio bearers used to send the transmit data at a data rate corresponding to the radio data service and examining the transfer buffer 2b to increase or decrease the number of the plural radio bearers established.

[0027] FIG. 2 illustrates transmission of a variable radio bearer in a method for controlling asymmetric dynamic radio bearers in a mobile packet data communications system according to the present invention. FIG. 3 illustrates the condition of a transmit buffer controlled by the method for controlling asymmetric dynamic radio bearers in a mobile packet data communications system according to the present invention. And, FIG. 4 is a flow chart illustrating a procedure for controlling asymmetric dynamic radio bearers in a mobile packet data communications system according to the present invention.

[0028] Now, reference will be made in connection with FIGs. 2 to 4 as to a detailed description of a method and apparatus for controlling asymmetric dynamic radio bearers in a mobile packet data communications system in accordance with the present invention.

[0029] First, the MAC 1a of the mobile station 1 requests the network 2 to provide a radio packet data service (S1).

[0030] Upon receiving a radio packet data service request message, the MAC 2a of the network 2 examines a data rate corresponding to the radio packet data service, establishing a plurality of radio bearers for the data rate as shown in FIG. 2 and sending data tempo-

rarily stored in the transfer buffer 2b to the plural radio bearers according to the radio packet data service (S2).

[0031] The mobile station 1 receives the transmit data according to the plural radio bearers for the data rate corresponding to the radio packet data service. Upon receiving the radio packet data service, the mobile station 1 sends the data corresponding to the radio packet data service or control signals, temporarily stored in the transmit buffer 1b, to the network 2 with the plural radio bearers at the data rate.

[0032] Here, FIG. 2 illustrates the station that the mobile station transmits the data service with the radio bearer (y kbps multiplied by 2) out of data rates (y kbps multiplied by 4) to the network 2 and the network 2 transmits the data service with the radio bearer (y kbps multiplied by 1) out of data rates (y kbps multiplied by 4) to the mobile station 1.

[0033] That is, the MAC 2a of the network 2 compares the amount of data temporarily stored in the transmit buffer 2b shown in FIG. 3 with a first threshold TH_{LOW} , and the MAC 1a of the mobile station 1 compares the amount of data corresponding to the radio packet data service or the amount of data according to the control signals, temporarily stored in the transmit buffer 1b, with the first threshold TH_{LOW} (S3).

[0034] If the amounts of data stored in the transmit buffers 1b and 2b are lower than the first threshold TH_{LOW} , the individual MACs 1a and 2a of the mobile station 1 and the network 2 check on whether a first internal timer T_{LOW} (not shown) is set. If the first timer T_{LOW} is not set, the individual MACs 1a and 2a reset a second timer T_{HIGH} (not shown), setting the first timer T_{LOW} at a first predetermined time and checking at predetermined time intervals on whether the amounts of data temporarily stored in the transmit buffers 1b and 2b are lower than the first threshold TH_{LOW} until the first predetermined time expires (S4-S7).

[0035] If the first timer T_{LOW} is set at the first time, the individual MACs 1a and 2a of the mobile station 1 and the network 2 check at predetermined time intervals on whether the amounts of data temporarily stored in the transmit buffers 1b and 2b are lower than the first threshold TH_{LOW} until the first predetermined time expires, respectively.

[0036] When the amounts of data temporarily stored in the transmit buffers 1b and 2b are lower than the first threshold TH_{LOW} for the predetermined time, the individual MACs 1a and 2a of the mobile station 1 and the network 2 decide that the amounts of data stored in the transmit buffers 1b and 2b are present in region "A", providing the radio packet data service with the number of the plural radio bearers for the predetermined data rate decreased by one and examining the amounts of data stored in the transmit buffers 1b and 2b at predetermined time intervals. The above procedure is repeated until the radio packet data service ends (S8).

[0037] If the amounts of data temporarily stored in the transmit buffers 1b and 2b are increased to be higher

than the first threshold TH_{LOW} before the first predetermined time expires, the individual MACs 1a and 2a of the mobile station 1 and the network 2 reset the first timer T_{LOW} , providing the radio packet data service with the plural radio bearers at the predetermined data rate and examining the amounts of data stored in the transmit buffers 1b and 2b at predetermined time intervals. The above procedure is repeated until the radio packet data service ends (S9).

[0038] On the other hand, when examining the amounts of data stored in the transmit buffers 1b and 2b at predetermined time intervals and repeating the above procedure, the individual MACs 1a and 2a of the mobile station 1 and the network 2 compare the amounts of data stored in the transmit buffers 1b and 2b with the first threshold TH_{LOW} inclusive of hysteresis values. Then, the individual MACs 1a and 2a provide the radio packet data service with the number of radio bearers decreased/increased by one, or unchanged according to the comparison result.

[0039] As shown in FIG. 3, the hysteresis value includes first and second hysteresis values $a1$ and $b1$ opposite to each other with the first threshold TH_{LOW} interposed therebetween and separated from the first threshold TH_{LOW} at a predetermined distance, and third and fourth hysteresis values $b2$ and $c1$ opposite to each other with the second threshold TH_{HIGH} interposed therebetween and separated from the second threshold TH_{HIGH} at a predetermined distance.

[0040] The first and second thresholds TH_{LOW} and TH_{HIGH} are between hysteresis values for preventing frequent changes of the amounts of data stored in the transmit buffers 1b and 2b.

[0041] That is, in a case where the amounts of data stored in the transmit buffers 1b and 2b change from area "A" to area "B" in FIG. 3, the individual MACs 1a and 2a compare the amounts of data stored in the transmit buffers 1b and 2b with the first threshold TH_{LOW} plus the second hysteresis value $b1$.

[0042] If the amounts of data stored in the transmit buffers 1b and 2b are kept lower than the first threshold TH_{LOW} plus the second hysteresis value $b1$ until the first predetermined time expires, the individual MACs 1a and 2a provide the radio packet data service with the number of the plural radio bearers decreased by one at the predetermined data rate and then examining the amounts of data stored in the transmit buffers 1b and 2b at predetermined time intervals. The above procedure is repeated until the end of the radio packet data service.

[0043] If the amounts of data stored in the transmit buffers 1b and 2b are increased to be higher than the first threshold TH_{LOW} plus the second hysteresis value $b1$, the individual MACs 1a and 2a of the mobile station 1 and the network 2 reset the first timer H_{LOW} , providing the radio packet data service with the number of the radio bearers unchanged and determining the amounts of data stored in the transmit buffers 1b and 2b at predetermined time intervals. The above procedure is

repeated until the end of the radio packet data service.

[0044] On the other hand, when the amounts of data temporarily stored in the transmit buffers 1b and 2b are higher than the first threshold TH_{LOW} , the individual MACs 1a and 2a of the mobile station 1 and the network 2 compare the amounts of data stored in the transmit buffers 1b and 2b with the second threshold TH_{HIGH} , respectively (S10).

[0045] When the amounts of data stored in the transmit buffers 1b and 2b are higher than the second threshold TH_{HIGH} , the individual MACs 1a and 2a of the mobile station 1 and the network 2 check on whether the second timer T_{HIGH} is set, and if not, setting the second timer T_{LOW} at a second time, and checking at predetermined time intervals on whether the amounts of data temporarily stored in the transmit buffers 1b and 2b are kept below the second threshold TH_{HIGH} until the first predetermined time expires (S11-S14).

[0046] If the second timer T_{HIGH} is set, the individual MACs 1a and 2a of the mobile station 1 and the network 2 check at predetermined time intervals on whether the amounts of data temporarily stored in the transmit buffers 1b and 2b keep higher than the second threshold TH_{HIGH} until the second predetermined time expires, respectively.

[0047] If the amounts of data temporarily stored in the transmit buffers 1b and 2b keep higher than the second threshold TH_{HIGH} until the second predetermined time expires, the individual MACs 1a and 2a of the mobile station 1 and the network 2 provide the radio packet data service with the number of radio bearers for the predetermined data rate increased by one and examining the amounts of data stored in the transmit buffers 1b and 2b at predetermined time intervals. The above procedure is repeated until the radio packet data service ends (S15).

[0048] If the amounts of data temporarily stored in the transmit buffers 1b and 2b are decreased to be lower than the second threshold TH_{HIGH} before the second predetermined time expires, the individual MACs 1a and 2a of the mobile station 1 and the network 2 reset the second timer H_{LOW} , providing the radio packet data service with the number of radio bearers unchanged at the predetermined data rate and examining the amounts of data stored in the transmit buffers 1b and 2b at predetermined time intervals. The above procedure is repeated until the end of the radio packet data service (S16).

[0049] On the other hand, when examining the amounts of data stored in the transmit buffers 1b and 2b at predetermined time intervals and repeating the above procedure, the individual MACs 1a and 2a of the mobile station 1 and the network 2 compare the amounts of data stored in the transmit buffers 1b and 2b with the second threshold TH_{HIGH} inclusive of hysteresis values. Then, the individual MACs 1a and 2a provide the radio packet data service with the number of radio bearers decreased/increased by one, or unchanged according

to the comparison result.

[0050] That is, the individual MACs 1a and 2a of the mobile station 1 and the network 2, as shown in FIG. 3, compare the amounts of data stored in the transmit buffers 1b and 2b with the second threshold TH_{HIGH} minus the fourth hysteresis value $c1$, respectively.

[0051] If the amounts of data stored in the transmit buffers 1b and 2b are increased to be higher than the second threshold TH_{HIGH} plus the fourth hysteresis value $c1$, i.e., change from area "B" to area "C" in FIG. 3, the individual MACs 1a and 2a of the mobile station 1 and the network 2 set the second timer T_{HIGH} at the second predetermined time.

[0052] When the amounts of data stored in the transmit buffers 1b and 2b are kept higher than the second threshold TH_{HIGH} minus the third hysteresis value $b2$ until the second predetermined time expires, the individual MACs 1a and 2a of the mobile station 1 and the network 2 provide the radio packet data service with the number of the radio bearers increased by one and examining the amounts of data stored in the transmit buffers 1b and 2b at predetermined time intervals. The above procedure is repeated until the end of the radio packet data service.

[0053] If the amounts of data stored in the transmit buffers 1b and 2b are decreased lower than the second threshold TH_{HIGH} minus the third hysteresis value $b2$, i.e., change from area "C" to area "B" in FIG. 3 before the second predetermined time expires, the individual MACs 1a and 2a of the mobile station 1 and the network 2 reset the second timer T_{HIGH} , providing the radio packet data service with the number of radio bearers unchanged and examining the amounts of data stored in the transmit buffers 1b and 2b at predetermined time intervals. The above procedure is repeated until the end of the radio packet data service.

[0054] When the amounts of data stored in the transmit buffers 1b and 2b are lower than the second threshold TH_{HIGH} , the individual MACs 1a and 2a check on whether the amounts of data stored in the transmit buffers 1b and 2b are between the first threshold TH_{LOW} and the second threshold TH_{HIGH} (S17).

[0055] If the amounts of data stored in the transmit buffers 1b and 2b are between the first threshold TH_{LOW} and the second threshold TH_{HIGH} , the MACs 1a and 2a reset the first and second timers T_{LOW} and T_{HIGH} , providing the radio packet data service with a predetermined number of radio bearers and examining the amounts of data stored in the transmit buffers 1b and 2b at predetermined time intervals. The above procedure is repeated until the radio packet data service ends (S18, S19).

[0056] If the amounts of data stored in the transmit buffers 1b and 2b are not between the first threshold TH_{LOW} and the second threshold TH_{HIGH} , the MACs 1a and 2a reset the first and second timers T_{LOW} and T_{HIGH} examine the amounts of data stored in the transmit buffers 1b and 2b and repeat the above procedure.

[0057] On the other hand, when examining the amounts of data stored in the transmit buffers 1b and 2b at predetermined time intervals and repeating the above procedure, the individual MACs 1a and 2a of the mobile station 1 and the network 2 compare the amounts of data stored in the transmit buffers 1b and 2b with the first threshold TH_{LOW} inclusive of hysteresis values. Then, the individual MACs 1a and 2a provide the radio packet data service with the number of radio bearers decreased/increased by one, or unchanged according to the comparison result.

[0058] That is, in a case where the amounts of data stored in the transmit buffers 1b and 2b belong to the area "B" of FIG. 3, the first and second thresholds TH_{LOW} and TH_{HIGH} inclusive of hysteresis values correspond to the first threshold TH_{LOW} minus the first hysteresis value a1 and the second threshold TH_{HIGH} plus the fourth hysteresis value c1, respectively.

[0059] For the amounts of data stored in the transmit buffers 1b and 2b belonging to the area "A" of FIG. 3, the first threshold TH_{LOW} inclusive of the hysteresis value corresponds to the first threshold TH_{LOW} plus the second hysteresis value b1. For the amounts of data stored in the transmit buffers 1b and 2b belonging to the area "C" of FIG. 3, the second threshold TH_{HIGH} inclusive of the hysteresis value corresponds to the second threshold TH_{HIGH} minus the third hysteresis value b2.

[0060] As described above, the hysteresis values have a buffering function when the amounts of data change from the area "A", "B" or "C" of FIG. 3 to around the first and second thresholds TH_{LOW} and TH_{HIGH} .

[0061] When the individual MACs 1a and 2a of the mobile station 1 and the network 2 are removed of all radio bearers, the radio packet data service is interrupted after a predetermined time. If there exists data to be transmitted within the predetermined time, the radio packet data service is resumed with the radio bearers added through a radio bearer adding procedure.

[0062] Even when using all the radio bearers initially assigned, the MACs 1a and 2a of the mobile station 1 and the network 2 can establish additional radio bearers in negotiation with each other as long as the amounts of data belong to the area "C" of the transmit buffers.

[0063] As described above, the method for controlling asymmetric dynamic radio bearers in a mobile packet data communications system according to the present invention involves use of the radio bearers for the specified data rate corresponding to the data rate according to the radio packet data service to activate a predetermined number of radio bearers only according to the amount of transmit data and vary the data rate. This makes it possible to efficiently use the radio resources and prevent excessive power consumption and signal interference.

[0064] It will be apparent to those skilled in the art that various modifications and variations can be made in the present invention without departing from the spirit or scope of the invention. Thus, it is intended that the

present invention cover the modifications and variations of this invention provided they come within the scope of the appended claims and their equivalents.

5 Claims

1. A method for controlling asymmetric dynamic radio bearers in a mobile packet data communications system, comprising the steps of:

(a) establishing a plurality of radio bearers having a predetermined data rate;

(b) examining the amount of data stored in a transmit buffer during transmission of mobile packet data; and

(c) transmitting the mobile packet data with the number of the radio bearers increased or decreased according to the amount of data.

2. The method as claimed in claim 1, wherein in the step (c), the amount of data stored in the transmit buffer is compared with first and second thresholds TH_{LOW} and TH_{HIGH} , and the number of the radio bearers is decreased by one when the amount of data is lower than the first threshold TH_{LOW} and increased by one when the amount of data is higher than the second threshold TH_{HIGH} .

3. The method as claimed in claim 2, wherein the number of the radio bearers is not changed when the amount of data stored in the transmit buffer is kept between the first and second thresholds TH_{LOW} and TH_{HIGH} .

4. The method as claimed in claim 1, wherein in the step (c), the number of the radio bearers is decreased by one when the amount of data stored in the transmit buffer keeps lower than the first threshold TH_{LOW} until a predetermined time expires and increased by one when the amount of data stored in the transmit buffer keeps higher than the second threshold TH_{HIGH} until the predetermined time expires.

5. The method as claimed in claim 4, wherein the first and second thresholds TH_{LOW} and TH_{HIGH} are between hysteresis values for preventing frequent changes of the amount of data stored in the transmit buffer.

6. The method as claimed in claim 4, wherein the hysteresis values comprise first and second hysteresis values are opposite to each other with the first threshold TH_{LOW} interposed therebetween and separated from the first threshold TH_{LOW} at a predetermined distance, and third and fourth hystere-

sis values are opposite to each other with the second threshold TH_{HIGH} interposed therebetween and separated from the second threshold TH_{HIGH} at a predetermined distance.

- 5
7. The method as claimed in claim 1, wherein the steps are supported in MAC (Medium Access Control) protocols of a mobile station and a network.
8. An apparatus for controlling asymmetric dynamic radio bearers in a mobile packet data communications system comprising: 10
- a transmit buffer for temporarily storing transmit data according to a radio data service; and 15
- controlling means for establishing a plurality of radio bearers for transmission of the transmit data at a data rate corresponding to the radio data service, examining the amount of data stored in the transmit buffer and increasing or decreasing the number of the radio bearers. 20
9. The apparatus as claimed in claim 8, wherein the controlling means is an MAC protocol. 25
10. The apparatus as claimed in claim 8, wherein the controlling means determines first and second thresholds for increasing or decreasing the number of the radio bearers. 30
11. The apparatus as claimed in claim 10, wherein the first and second thresholds TH_{LOW} and TH_{HIGH} are between hysteresis values for preventing frequent changes of the amount of data stored in the transmit buffer. 35
12. The apparatus as claimed in claim 11, wherein the hysteresis values comprise first and second hysteresis values are opposite to each other with the first threshold TH_{LOW} interposed therebetween and separated from the first threshold TH_{LOW} at a predetermined distance, and third and fourth hysteresis values are opposite to each other with the second threshold TH_{HIGH} interposed therebetween and separated from the second threshold TH_{HIGH} at a predetermined distance. 40
- 45
- 50
- 55

FIG. 1
Related Art

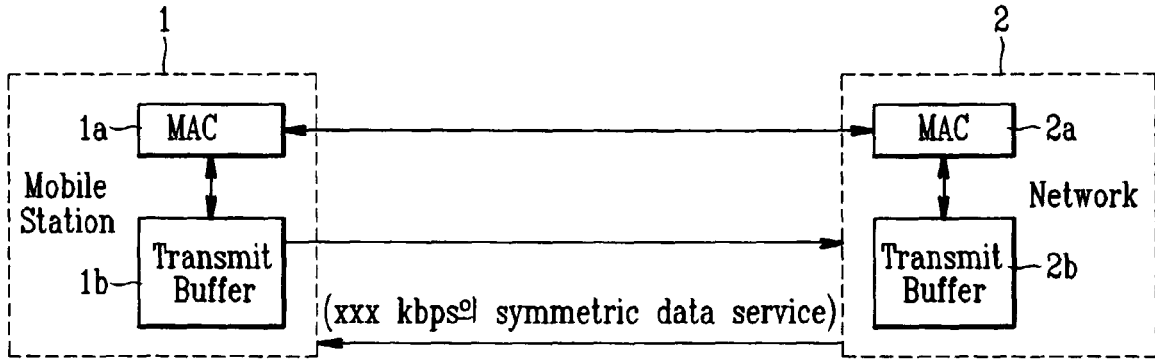


FIG. 2

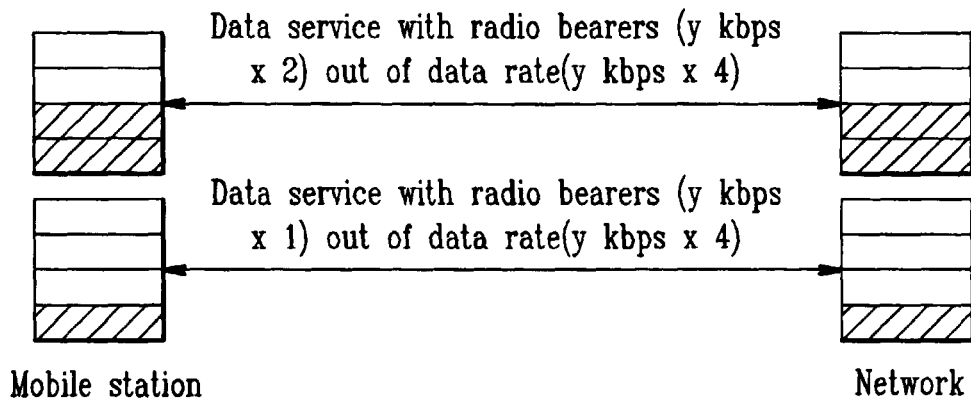


FIG. 3

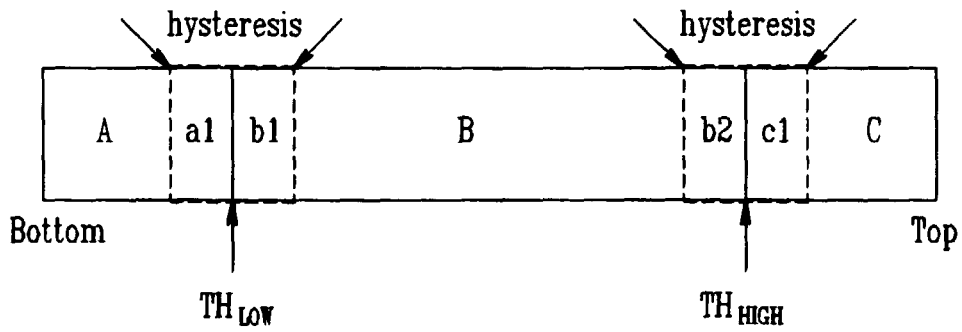


FIG. 4

